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Surface Texturing of Casting Belts of Continuous Casting Machines

TECHNICAL FIELD

This invention relates to the control of heat flux in a continuous belt-casting machine used for continuously casting a molten metal in the form of a strip. More particularly, the invention relates to the surface texturing of the casting belts used in such machines.

BACKGROUND ART

Continuous casters, such as twin belt casters, single belt casters and recirculating block casters, are commonly used for producing strip ingots (continuous metal strips) from molten metals, particularly aluminum alloys. In casters of this kind, a casting cavity is formed between continuously moving casting surfaces and molten metal is introduced into the casting cavity on a continuous basis. Heat is withdrawn from the metal via the casting surfaces and the metal solidifies in the form of a strip ingot that is continuously withdrawn from the casting cavity by the moving casting surfaces. The heat flux through the casting surfaces (heat extracted from the solidifying metal) must be carefully controlled to achieve cast strip ingots of good surface quality and to avoid distortion of the casting cavity. Different metals (e.g. aluminum alloys) require different levels of heat flux for proper casting on a continuous basis, so it is important to be able to control the casting apparatus to provide the required levels of heat flux for a particular metal being cast.

The primary heat flux control is usually achieved by applying cooling water to the casting belts or blocks. In most belt casters, this is done on the back face of the belt in the region where the belt passes though the casting cavity. However, the heat flux is often adjusted more precisely by additional means. For example, belt casters have been provided with porous ceramic coatings over the metal belts. Such coatings may optionally be partially or completely filled with a high conductivity inert gas, such as helium, to provide further refinement. In such cases, the expense of maintaining a consistent

conductivity (such as copper), and by reducing the amount of liquid parting layer. Conventional texturing as applied to such high conductivity belts reduces the maximum high heat flux capability, yet elimination of such texturing can lead to problems of meniscus stability during casting.

U.S. Patent No. 6,063,215 issued on May 16, 2000 to Donald G. Harrington discloses a steel casting belt which is textured in a more regular manner, i.e. it teaches transverse grooves or dimples provided on a steel casting surface. This textured steel belt is then artificially oxidized. The texturing is said to promote a more uniform heat transfer and allow for escape of gases that may form during casting. Such belts are used in casters where the belt is cooled in a area remote from the casting cavity, and does not use a parting agent.

U. S. Patent No. 6,135,199 issued on 24 October 2000 to Gavin Wyatt discloses a belt caster where the belts may have fine longitudinal grooves, but refers to US Application No 08/543,445 (which issued by continuation as US Patent No. 6,063,215) as being the preferred embodiment.

Therefore, there is a need to provide an improved casting belt having a the high heat removal capability characteristic of a casting belt directly cooled by coolant on its reverse face, while providing for a stable casting process with no distortion in the belt.

DISCLOSURE OF THE INVENTION

According to one aspect of the invention, there is provided a continuous belt casting apparatus, comprising a casting cavity, at least one (preferably two) flexible metal belt having an elongated casting surface passing through and at least partially defining the casting cavity, a motor for rotating said at least one metal belt in a longitudinal direction of said casting surface whereby said casting surface passes through said casting cavity in said longitudinal direction, and a molten metal supply device adapted to deliver molten metal continuously to the casting cavity, whereby molten metal

remove from the cavity a solidified strip ingot formed as said molten metal solidifies in the casting cavity, wherein said casting surface is provided with a plurality of grooves oriented in substantially the same direction.

According to yet another aspect of the invention, there is provided a casting belt adapted for use in a continuous belt caster, said casting belt comprising a flexible metal belt having an elongated casting surface provided with a plurality of grooves oriented in substantially the same direction

In the present invention, the grooves are preferably oriented in a direction less than 45 degrees (more preferably less than 20 degrees, and ideally less than 10 degrees or even less than 5 degrees) from the longitudinal direction of the belt, and most preferably are oriented substantially in the longitudinal direction of the belt. Preferably, the entire casting surface of the belt(s) is provided with the grooves and the grooves are substantially contiguous cross-wise of the belt so that, if they are separated by flat ungrooved lands, such lands have a width less than the width of the adjacent grooves.

A further understanding, aspects and advantages of the present invention will be realized by reference to the following description, appended claims and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is described in more detail below with reference to the accompanying drawings, in which:

Fig. 1 is a simplified side view of a continuous twin-belt casting machine which can be used in the present invention;

Fig. 2 is an enlarged view of the exit portion of the casting machine in Fig. 1;

Fig. 3 is a graphical representation of the surface of a casting belt in

to as a "molding gap" or a "moving mold") therebetween, i.e. between casting surfaces of the belts. The casting cavity 22 can be adjusted in width by means of edge dams (not shown), depending on the desired thickness of the aluminum strip being cast. The pair of belts run substantially parallel to each other in the casting cavity, preferably with some degree of convergence. A molten metal is continuously supplied into the casting cavity 22 in the direction of the arrow 24 via entrance 25 while the belts are chilled, in the region of the casting cavity, at their reverse faces, for example, by direct impingement of coolant liquid 20 on the reverse surfaces. The cast strip then emerges from exit 26 in the direction of arrow 27.

In the illustrated apparatus, the path of the molten metal being cast is substantially horizontal with a small degree of downward slope from entrance 25 to exit 26 of the casting cavity.

Molten metal is supplied to the casting cavity 22 by a suitable launder or trough (not shown) which is disposed at the entrance 25 of the casting cavity 22. For example, the molten metal injector described in U.S. Patent No. 5,636,681, which is assigned to the same assignee as the present application, may be used for supplying molten metal to the casting machine 10. Although not shown, an edge dam is provided at each side of the machine so as to complete the enclosure of the casting cavity 22 at its edges. It will be understood that in the operation of the casting machine, the molten metal supplied to the entrance 25 of the casting cavity 22 advances through the casting cavity 22 to the exit 26 thereof by means of continuous motion of the belts 12, 14. During the travel along the casting cavity (moving mold) 22, heat from the metal is transferred through the belts 12, 14 and removed therefrom by the supplied coolant 20, and thus the molten metal becomes progressively solidified from its upper and lower faces inward in contact with the casting surfaces of the belts. The molten metal is fully solidified before reaching the exit 26 of the casting cavity and emerges from the exit 26 in the form of a continuous, solid, cast strip 30, the thickness of which is determined by means of the width of the casting cavity 22 as defined by the casting

micrometers).

Fig. 3 is a representation of the casting surface of a casting belt showing, in exaggerated form, a surface texture in accordance with a preferred form of the present invention, i.e., surface grooves provided in the casting surface of the belts. The casting direction (direction of movement of the belt) is shown by arrow 31. In the preferred embodiment of Fig. 3, the grooves provide to the casting surface a roughness in a range of 18 - 80 micro-inches (0.46 to 2.0 micrometers), preferably 18 - 65 micro-inches (0.46 to 1.65 micrometers), more preferably 25 - 45 micro-inches (0.64 to 1.14 micrometers), in units of conventional average surface roughness (R_a). The surface roughness value (R_a) is the arithmetic mean surface roughness. This measurement of roughness is described, for example, in an article by Michael Field, et al., published in the Metals Handbook, Ninth Edition, Volume 16, 1989, published by ASM International, Metals Park, Ohio 44073, USA, pages 19 to 23; the disclosure of which is incorporated herein by reference. Fig. 4 is a cross-section of a part of the surface illustrated in Fig. 3 (transverse to the casting direction 31), showing the roughness arithmetic average (R_a) of the peaks P and valleys V of the surface. There are several ways of measuring surface roughness that are well known to persons skilled in the art.

It has been found that, if the roughness (R_a) of the belt is less than about 18 micro-inches (0.46 micrometers), the meniscus becomes unstable resulting in surface defects, and the interior of cast strip suffers from porosity and other casting defects. If the roughness of the belt exceeds 80 micro-inches, the surface of the cast strip has exposed dendrites (referred to as "frost") or exudates (referred to as "blebs"), although the interior of the slab may be sound. The upper limit is somewhat alloy-dependent and therefore a particularly preferred upper limit of 80 micro-inches may be used to cover the broadest range of alloys. However, it has been found that the roughness of 18 to 65 micro-inches is more preferable, and the roughness of 25 - 45 micro-inches is even more preferable, as shown the examples which is hereafter described in detail.

The disclosure of this patent is incorporated herein by reference. The structure and operation of these devices are briefly explained below. Fig. 5 shows a simplified cross-section of part of a belt casting machine showing parting layer removal device 32. Fig. 6 schematically illustrates a device for applying a new layer of parting agent to a casting surface, and Fig. 7 is a simplified longitudinal vertical cross-section of Fig. 6.

In Fig. 5, there is shown a part of an upper belt 12 at the exit end of the casting cavity of the twin-belt casting machine 10 (Fig. 1). The molten metal solidifies as a strip 30 in contact with casting surface 12a moving in the direction of arrow 27. A portion 12c of the belt 12 is newly released from contact with the solidified metal strip and has a surface coating of a parting agent contaminated with detritus following contact with the hot metal. A new layer of liquid parting agent is applied to the return surface 12b of the belt at a station (not shown in Fig. 5, but see Figs. 6 and 7) upstream of the injector for applying the molten metal layer.

The parting layer removal device 32 is positioned adjacent to the belt 12 for the purpose of completely removing the old parting agent and detritus from the surface of the belt before the fresh new parting agent is applied. The removal device 32 consists of a hollow casing 34 extending across the width of the belt and closed on all sides except at an open side 36 facing an adjacent surface of the belt 12. A spray bar 38 with flat spray nozzles is positioned within the casing 34 and directs a high pressure spray of a cleaning liquid. The spray of cleaning liquid removes most of the parting liquid and contaminating detritus from the surface of the belt as the belt moves past the removal device 32. Any residual cleaning liquid or detritus on the belt surface is removed by a scraper 40.

The removal device 32 makes it possible to remove a contaminated layer of parting liquid and solid detritus from the belt surface quickly, efficiently and continuously so that the casting surface of the belt 12 emerging from the casting cavity 22 is completely clean and ready for the application of a fresh

surface was obtained using a portable profilometer (5.60 mm evaluation length with a 0.8 mm cut-off), as well as from replicas taken of the freshly prepared belt surface. Casting was performed at different casting speeds and under different heat flux conditions.

Cast slab surface quality was determined from the surface appearance; a number rating system (1 through 5) was developed with the better quality being attributed a low number. It was determined that the best slab surface quality was obtained when using belts prepared with measured R_a roughness values in the range of 25 to 45 micro-inches (0.46 to 1.14 micrometers). Under certain casting conditions, this range may be extended to a range of 18 to 80 micro-inches (0.46 to 2.0 micrometers). Table 1 gives the average roughness value (R_a) and the resulting assessment of the overall effect on the cast strip.

TABLE 1

Cast quality depending on surface roughness values

Roughness (Ra) in micro-inches	Cast quality	Remarks
16	Surface defects resulting from meniscus instability and internal porosity	Unacceptable
25	Good quality surface and good interior	Good
45	Generally good quality surface and good interior	Good
65	some surface "frost", good interior	Acceptable
80	Extensive surface "frost" or "blebs", interior good	Unacceptable

While the present invention has been described with reference to several preferred embodiments, the description is illustrative of the invention and is not to be construed as limiting the invention. Various modifications and